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ANALYSIS OF THE GRAMMAR AND LOGIC OF 'IF' IN GRADE SIX SCIENCE TEXTBOOKS

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Analysis of the Grammar and Logic of 'If' in Grade Six Science Textbooks submitted by Daria Gural Malo in partial fulfilment of the requirements for the degree of Master of Education.

ABSTRACT

Relational words have been found to present reading comprehension difficulties to children partly because of their abstract nature and also because of their diverse meanings and functions. Words such as 'if' which have grammatical as well as logical functions are perhaps most difficult for children to understand.

Children do not have complete control of the grammar or the logic of 'if' and therefore they would be expected to have difficulty processing sentences containing 'if.' Where 'if' is used as a logical construct in 'if-then' propositions which require conditional reasoning, immature cognitive development may prevent children from reasoning conditionally.

The purpose of this study was to determine the extent to which 'if' is used in grade six science textbooks, and the ways in which it is used grammatically and logically in textbook sentences. Certain syntactic processes which complicate the grammar and logic of 'if' and which hinder processing of the entire sentence were also investigated.

Three science textbooks recommended for use in Alberta's grade six classes were analyzed. Initially, 686 sentences containing 'if' found in the three textbooks were isolated and recorded. The sentences were then subjected to a variety of counts relating to the grammar and logic of 'if.'

It was found that 'if' has several meanings and differential uses in science textbook sentences. It is used most fequently to indicate supposition. The conditional 'if' and 'if' to mean 'whether'

are also used to a large degree. Many sentences were found to reverse the logical 'if-then' form, and the vast majority of sentences delete 'then' from 'if-then' statements. The question transformation involving use of 'if' to indicate supposition is used extensively by one textbook in particular. Various forms of negation, which are also forms of propositional logic, were also identified.

Because multiple meanings and functions of 'if,' and a variety of grammatical and logical complexities characterize the textbook sentences, children would be required to have a thorough understanding of the grammar and logic of 'if' to which they are exposed in their reading of science textbooks.

On the basis of the findings it was suggested that teachers be made aware of the high frequency of 'if' sentences in science textbooks and the reading comprehension difficulties they may present. Textbook writers and evaluators need to consider these difficulties in material written for children.

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Chapter 1

THE PROBLEM: ITS NATURE AND SIGNIFICANCE

Introduction

The word 'if' is used often in everyday life by adults and children. It is a word children meet early in their reading because it poses no problems in word recognition. It is not included in vocabulary studies because teachers consider it part of each child's repertoire of words. As a result, 'if' is treated with casual disregard by writers, teachers and pupils in all contexts and in all areas of study in school.

The grammatical word 'if' has, in fact, several meanings, as do many function words. Although its role is to relate ideas, the relationships may assume several forms. But 'if' also has a logical function in propositional reasoning, particularly in conditional logic.

Science textbooks make special use of 'if' in both its grammatical and logical roles. The 'if then' sentence is basic to hypothetico-deductive reasoning in science, and cursory examination of science textbooks revealed 'if' is frequently present in sentences in science textbooks used in all grade levels.

Teachers of science have long complained that children have difficulty getting information from science textbooks. Full reading comprehension demands understanding of the written message according to the author's intended meaning. Children apparently fail to derive the necessary meaning from science textbooks in spite of readability

controls.

One major source of reading comprehension difficulties in science textbooks may be the relating and interrelating of rather abstract ideas. Research by Rawson (1969), Robertson (1966), Davison (1968) and others has shown that it may be relational words like 'if' which present the greatest problems in reading comprehension.

In science textbooks 'if' can be used to relate ideas grammatically, but it can also have a logical function in relating ideas in conditional forms. Conditional logic requires reasoning on the basis of the logic of 'if.' Research by Piaget and his associates and by Ennis (1965) has shown that ability to reason conditionally occurs late in the intellectual development of children. Children will conceivably encounter problems when they are asked to process sentences which contain 'if-then' propositions.

The Problem

If relational words such as 'if' are difficult for children to understand, and if conditional reasoning using 'if' occurs late in children's cognitive development, then teachers must teach children the grammar and logic of 'if' to help them achieve full comprehension of sentences using 'if.' In order that teachers may decide which structures relating to 'if' need to be taught, it is first necessary to know the structures containing 'if' which are actually present in textbooks written for children.

It is the purpose of this study to determine the extent to which children in grade six are exposed to 'if' in various contexts in

science textbooks, to delineate types of conditional logic necessary to process the sentences, and to examine some of the syntactical aspects of 'if' sentences which may hinder the processing of the grammar and logic of 'if' and of the sentence as a whole.

Research Questions

The following questions were formulated with the purpose of this study in mind.

1. What is the frequency and distribution of sentences containing 'if' in the three science textbooks recommended by the Department of Education to be used by grade six pupils in Alberta?

2. What is the total number of times the word 'if' is used in the sentences in the textbooks?

3. What are the differential uses of 'if' according to differences in meaning of the word 'if' in these sentences?

4. What are the sentence positions in which 'if' is located?

5. To what extent is the question transformation used in sentences containing 'if' in the three textbooks?

6. How often is 'then' stated in 'if-then' sentences, and to what extent is it deleted but implied?

7. What use is made of negative expansion and what are the effects of negation on the logical forms of sentences containing 'if'?

Limitations

The following limitations of the design of the study are acknowledged.

1. This study analyzed only sentences containing 'if' in three science textbooks at one grade level.

2. Only certain specific grammatical features of 'if' sentences were examined. For this reason it is impossible to offer any definitive answers on the comprehensibility of the sentences analyzed or on the textbooks.

3. No attempt was made to test children's understanding of the word 'if' and the sentences in which it is used.

Definition of Terms

A number of expressions focal to this study are used repeatedly in the writing of this report. These terms as expressed and used in this investigation are explained.

Sentence: That part of written discourse that extends from a capital letter to a period, a question mark, or an explanation mark.

Grammar: The phenomena dealing with the study of words, including their meanings, functions, and syntactical relations.

Syntax: The arrangement of words in sentences.

Logic: A branch of thought or reasoning that is concerned with the objective relation between evidence and conclusion.

Deductive Reasoning: Reasoning from a given premise to a necessary conclusion by means of logical rules.

Inference: An opinion, belief, or conclusion drawn from evidence or from other opinions or beliefs considered to be evidence.

Conditional Reasoning: Reasoning on the basis of a statement composed of two component statements joined by the connective 'if . . . then.'

<u>Conditional Logic</u>: A type of deductive reasoning dealing with statements containing the word 'if' which introduces conditions upon which the truth of the rest of the sentence containing them depends.

<u>Readability</u>: Ease of understanding of written discourse, often obtained by the application of a formula.

<u>Comprehensibility</u>: Full understanding of written discourse relevant to the author's thought and intended meaning.

<u>Frequency</u>: The total number of times an element is found in the textbook sample.

<u>Distribution</u>: The number of times an element is found in individual textbooks used in the sample.

Significance of the Study

The results of this study may have implications for classroom teachers, for textbook writers and editors, and for those charged with evaluating textbooks to be used by children in the elementary grades.

Several meanings of 'if' will be offered so that teachers may become aware of multiple meanings and differential uses of 'if' and teach them to their pupils.

The logic of 'if' will be examined so that teachers will be cognizant of the logical functions of 'if' and the types of conditional logic to which children are exposed in their science textbooks.

Several grammatical processes present in 'if' sentences that

increase their syntactical and logical complexity will be presented. Teachers need to be aware of the additional difficulties these may present their pupils, and teach pupils to analyze and to understand them.

Textbook writers, editors and evaluators must recognize the difficulties various grammatical and logical aspects of 'if' may create for children. These will need to be controlled and explained thoroughly as they are presented in the textbooks. When this is done children will be given textbooks which are not only readable, but comprehensible.

Overview of the Investigation

Three science textbooks authorized by the Department of Education, Province of Alberta, for children in grade six were analyzed for the presence of sentences which contain 'if.' The frequency and distribution of every sentence containing 'if' were tabulated. The sample was also subjected to a variety of counts relating to the grammar and logic of 'if' and the syntax of the sentences in which it is used.

A review of research related to this investigation is presented in Chapter 2. Chapter 3 describes the research design, and Chapter 4 reports the analysis of textbook findings. The concluding chapter summarizes the findings and conclusions of the investigation, the implications of the study, and suggests possible related research.

Chapter 2

REVIEW OF RELATED LITERATURE AND RESEARCH

This chapter presents a review of related literature and research which served both as a stimulus to and a theoretical basis for the present study.

Most children in the upper elementary grades in school have acquired the ability to read written work independently insofar as they are able to decode printed symbols. Difficulties in reading comprehension, nevertheless, are almost always present particularly when the reading involves textbooks in the content subjects. This is the case even when concept load, vocabulary and sentence length are controlled in material written for children.

Language structures in print frequently differ from structures used in oral communication. It is recognized that written language is not simply "speech written down." The language of print is usually more formal, compact and contains a greater number of compound and complex sentences. Many sentences children are required to read have a very involved structure. The relation of ideas in these sentences and relations between sentences may create difficulties in comprehension.

Particular difficulties in comprehension may result from children's independent reading of textbooks in social studies, science and mathematics which contain specialized patterns of writing. Science textbooks make special use of causal and implicative relations.

Mathematics is full of 'if . . . then' propositions. Reasoning in mathematics and the solving of mathematical problems is dependent primarily on full comprehension in reading the relationships expressed in print. Knowing isolated word meanings, including specialized vocabulary, is a prerequisite but it will not ensure full comprehension of connected discourse in these subject areas.

Reading and Reading Comprehension

The Nature of Reading Comprehension

Historically most reading authorities have defined reading as a cognitive process which is never mere decoding of printed symbols. Thorndike first stated that "reading is thinking" in 1917. As a thinking process, reading involves comprehension.

In 1970 Stauffer summarized the position of experts on the role of comprehension in reading.

> Universal agreement can be obtained supporting the conclusion that comprehension is the invariant condition of reading. Almost universal agreement can be obtained regarding the conclusion that reading is a process akin to thinking. Some few agree that if the first two premises are true then reading should be taught as a thinking process (p. 138).

The Reading Handbook (1968) currently used in the Province of Alberta describes reading as an act which "involves complex mental processes. Reading takes place only when the individual gets meaning from the material and is able to make use of the ideas obtained" (p. 6).

Jenkinson (1973) defines reading as more than creating meaning from printed symbols.

> Constructing meaning is a vital prerequisite of all reading. But reading is also a form of thinking, problem-solving or reasoning, which involves analysis and discriminating, judging,

> evaluating, and synthesizing. . . . Any definition of the reading process, therefore, must include interpretation and evaluation as well as construction of meaning (p. 45).

Smith and Barrett (1974) agree that reading comprehension is not a global process, but "a diverse ability with many discriminate subabilities" (p. 49). A global conceptualization of reading comprehension tends to lead to a definition of comprehension as "getting meaning" from the printed page. The result has been an overemphasis in schools on comprehension tasks which require recognition and recall of explicit statements read by students.

This concern was borne out in a study by Guszak (1967). Guszak investigated the types of reading comprehension teachers in the elementary grades stimulated through their oral questions. The findings showed that the vast majority of the teachers' questions required literal recognition or recall. Evaluation questions were the second most frequently asked. However, Guszak indicated that most of these questions required only "yes" or "no" responses. Third in order of frequency were inferential questions, that is, conjecture and explanation combined. Answers to these questions were usually based on children's individual imaginations and emotions, the result of idiosyncratic and creative thinking rather than critical thinking.

On the basis of his findings, Guszak concluded that there was an overemphasis on literal questions, and recall questions in particular, about minute and insignificant facts. Perhaps more importantly, these results imply that teachers generally do not determine the quality and degree of comprehension obtained by their

pupils from their reading according to the intended message. Moreover, it is safe to conclude that the teaching of reading fails to guide children in the use of thinking processes so that full comprehension is attained relevant to the writer's thought.

Reading Comprehension Skills

Experts in the field of reading have long been aware of the complexity of reading comprehension. Until recently, however, little has been offered in the way of explanation of this complexity. Thomas Barrett developed a Taxonomy of Reading Comprehension in an effort to help teachers to gain a clear understanding of reading comprehension. The Taxonomy attempts to define and classify reading comprehension skills, and is based on the works of Bloom (1956), Guilford (1958), and Guszak (1967).

In its original form, "The Barrett Taxonomy of Reading Comprehension" presented by Clymer (1968) postulates five dimensions of thinking in reading: literal comprehension, reorganization, inferential comprehension, evaluation, and appreciation. In 1972 Barrett revised the Taxonomy by omitting the reorganization operation. The four major categories of reading comprehension presented by Smith and Barrett (1974) are literal recognition or recall, inference, evaluation, and appreciation.

Barrett considers literal comprehension to be basic and fundamental to ability to deal with other types of comprehension tasks. In addition, Barrett notes that there are differences in difficulty among literal comprehension tasks. For example, the more discrete items of information the reader is asked to recognize or recall, the

more difficult the task. The sequence in which items of information are presented may further add to the difficulty.

The second category of reading comprehension in Barrett's Taxonomy, inferential comprehension, involves on the part of a student "a synthesis of the literal content of a selection, his personal knowledge, his intuition and his imagination as a basis for conjectures or hypotheses" (Smith and Barrett, 1974, p. 54). This task may require convergent or divergent thinking which goes beyond the printed page.

Tasks of convergent inference, according to Smith and Barrett involve inferences based primarily upon the data or information provided by the author and the logic rather than the imagination of the student. These tasks will produce inferences or conclusions which can be confirmed by the information provided by the author. The thinking processes require the ability to use inductive and deductive logic. Tasks that require this ability should help students to analyze and synthesize information, and to draw logical conclusions from given data or premises.

The third category in Barrett's Taxonomy of reading comprehension is evaluation. Evaluation requires that judgements be made about the content being read, "judgements that have to do with its accuracy, acceptability, worth, desirability, completeness, suitability, timeliness, quality, truthfulness, or probability of occurrence" (Smith and Barrett, 1974, p. 55).

Evaluation involves the making of both positive and negative judgements. Smith and Barrett stress that evaluation itself demands

that the reader be systematic, logical and objective when evaluating what is read. More importantly, it is vital that the reader reserve judgement until adequate data are available, and so avoid opinions, overgeneralizations, and leaping to conclusions.

The last category in Barrett's Taxonomy, appreciation, involves the affective domain according to Bloom's Taxonomy (1956). Appreciation is concerned primarily with the reader's emotional reaction to the content.

The categories and tasks to be included in reading comprehension differ somewhat among experts in the field, but there are many similarities. Jenkinson (1973) lists three broad categories of reading comprehension: construction, interpretation, and evaluation of meaning, which are roughly analogous to the first three categories in Barrett's Taxonomy. The first of these, construction of meaning, occurs at the literal level and is a prerequisite to all reading. Beyond the understanding of the direct meaning of a passage, comprehension must also include inferred meanings and implications. Interpretation and evaluation, according to Jenkinson, demand reading between the lines and are based on past experience:

> To derive full comprehension, a reader must first become the co-author, suspending judgements until he has absorbed the concepts presented, and then scrutinizing and assessing the ideas in the light of his own knowledge and experience (p. 45).

Readability of School Textbooks

In an attempt to ensure that children in various grades in schools are able to understand material read by them, experts in the field of reading began to study readability and the means of predicting

it. Readability is usually defined as ease of understanding. Interest in determining difficulty of reading material by means of readability formulas began early in this century. A readability formula uses counts of language variables in order to provide an index of difficulty for average readers at various grade levels in school.

Traditional Formulas Used to Determine Readability

Chall (1958) reported that the earliest published studies in readability estimated difficulty of reading materials on the basis of one factor, vocabulary. Later, one aspect of language structure, sentence length, was added as a second variable in readability formulas. Examples of these formulas, developed in 1948 and still commonly used today, are the Lorge, Flesch, Dale-Chall, and Dolch formulas. They have been used to determine readability of all textbooks, without distinguishing between narrative material usually present in developmental reading programs, and non-fiction, informational material used in content subjects.

There is general agreement among teachers that students of all ages encounter problems with reading in content areas. There is concern that children's textbooks in content subjects such as social studies and science are too difficult for the intended grade levels. Teachers of science, for example, have long been aware that the reading level of science textbooks as determined by various readability formulas is too difficult for their pupils.

Readability of Three Science Textbooks as Determined by Traditional Formulas

The concern that science textbooks are too difficult for children prompted Kass and Jacknicke (1971) to study the readability of elementary science textbooks widely used in the Province of Alberta. Three science textbooks at each of three grade levels, four, five and six, were used in the research: Barnard et al., Science for Tomorrow's World (1966), Brandwein et al., Concepts in Science (1966), and Fischler et al., Science a Modern Approach (1966).

From each book the investigators selected for examination five passages each approximately one hundred words in length at one-fifth intervals throughout each book. Every passage selected was then subjected to two readability formulas, the Dale-Chall Readability Formula, and the Fog Index. Both formulas are based on average sentence length and percentage of difficult words.

The findings indicate that for each book at each grade level, the average readability is above the grade level for which it is intended. Table 2.1 shows the average reading levels of the three textbooks as presented by Kass and Jacknicke (1971, p. 1).

Although the Fog Index tends to ascribe higher average readability levels to the textbooks, the results of both formulas indicate that these science textbooks require above-average reading ability. Kass and Jacknicke also report finding considerable variation in reading difficulty in different parts of some books.

The problem of high readability of these textbooks is compounded by the wide spread in reading ability in every classroom. Using a simple rule of thumb as 2/3 x grade level = minimum spread of reading

Table 2.1

Average Readability Levels of Three Elementary Science Textbook Series

	Dale-Chall Readability Formula	Fog Index
	Average Reading Grade Level	Average Reading Grade Level
Grade 4		
Barnard et al.	5 to 6	7.2
Brandwein et al.	5 to 6	8.1
Fischler et al.	7 to 8	8.9
Grade 5		
Barnard et al.	7 to 8	8.9
Brandwein et al.	7 to 8	7.3
Fischler et al.	7 to 8	8.3
Grade 6		
Barnard et al.	7 to 8	7.3
Brandwein et al.	7 to 8	8.9
Fischler et al.	9 to 10	11.3

ability, Kass and Jacknicke note that there would be a minimum spread of four years in reading ability in a typical grade six class. This would indicate that some pupils would be reading at the grade seven or eight level while others may be reading at the grade three or four level.

Utilizing a ranking of readability according to three informal levels, independent reading level, instructional reading level, and frustration reading level (Johnson and Kress, 1965), the readability of all three science textbooks would be at the frustration level for the vast majority of pupils at each grade level. It is most likely that these textbooks are required to be read independently by the children. The independent reading level requires at least 90 percent comprehension (Betts, 1946). At best, the children would receive a minimum of instruction from science teachers in interpreting some of the information in the textbooks. The instructional reading level, however, demands that the material not be too difficult, yielding at least 60 percent comprehension (Spache, 1964).

Kass and Jacknicke conclude that the textbooks used in their study would present excessive difficulty to many children who are reading in what is considered the average range (grade level plus or minus one). Extreme frustration could be anticipated using these materials with children reading considerably below grade level.

Limitations of Readability Formulas in Assessing Textbooks in Content Subjects

It is possible that the traditional approach to determining readability of content subject textbooks by the use of readability

formulas fails to measure reading difficulty accurately because it does not take into account the specialized writing used in these textbooks. The specialized language includes not only vocabulary and concept difficulty of specific terms, but the syntax or style in which the information is conveyed. The style involves not only syntactic or grammatical complexity, but the relation and interrelation of rather abstract ideas which results in logical complexity. It is safe to assume that an index of reading difficulty based on all factors of syntactic and logical complexity would rate content subject textbooks much higher than do traditional readability formulas.

Pennock (1974) postulates another reason for traditional readability formulas underestimating the difficulty of non-fiction materials such as textbooks in science. Most readability formulas are based on a criterion of 50 percent comprehension. A 50 percent comprehension score may well be insufficient for learning material. Research has shown that 60 percent is a minimum level of comprehension at the instructional level for maximum learning of information to occur (Spache, 1964; Bormuth, 1969).

Advantage of Cloze Procedure in Determining Textbook Readability

Bormuth (1964) advocates the use of the cloze technique for assessing the reading comprehension of children in the upper elementary grades. He also suggests that the cloze procedure be used as a means of determining readability in content subject areas which use specialized vocabulary (Bormuth, 1967).

The cloze procedure, developed by Taylor (1953) refers to

omitting every -nth word from material to be read, and replacing the deleted word with a blank. The reader is required to fill each blank with a word appropriate to the context in terms of both meaning and grammar. The degree of comprehension is the extent to which a person who has read the passage can replace the deleted words correctly. Those passages on which higher scores are obtained will be regarded as more readable than those on which lower scores are obtained.

The cloze procedure of assessing reading comprehension, and thereby textbook readability, allows the reader to use his knowledge of language patterns and his ability to respond to contextual clues. It would also necessitate relating and interrelating facts and ideas, and so would determine the reader's ability to do this correctly. This would yield a more valid index of reading comprehension or comprehensibility of textbooks. The cloze procedure also provides a means of analyzing which words, phrases, sentences or relationships produce the greatest difficulty.

Recently Daugs (1974) investigated the readability of a high school biology textbook used in grade ten by means of the cloze procedure. On the basis of his investigation Daugs found that informal reading inventories and cloze scores indicate that readability formulas score the readability of textbooks too low.

Need to Consider Syntactic Complexity in Readability

An application of transformational grammar analysis to readability data obtained by the cloze procedure has merit as a means

of determining which grammatical factors within a sentence contribute to its difficulty. The specialized style of writing may be the most critical factor in the reading difficulty of textbooks in the content subjects.

In recent years there has been great interest in the development and application of syntactic complexity formulas to determining readability. A syntactic complexity formula developed by Botel and Granowsky in 1972, and Botel, Dawkins and Granowsky in 1973, both reported by Dawkins (1975) was devised basically by identifying as many of the elements of syntax as possible and rating them on a hierarchical scale. Dawkins suggests that this formula can be checked by using it on a variety of selections and comparing the results with that of traditional formulas.

Grammatical Processes in Syntactic Complexity

Although children can speak and comprehend many types of sentences when they enter school, differences between oral and written language will cause difficulties for children when interpreting written material. This is due at least in part to the greater variety and complexity of language patterns and arrangements in print. To facilitate comprehension, writers of children's books attempt to control the complexity of written language.

Ruddell (1965) studied the relationship between syntactic structure of written language and reading comprehension of elementary school children. His research found that comprehension was greatest on patterns of written language which most closely correspond to

their oral language patterns.

Textbooks in content subjects such as mathematics and science use specialized styles of writing appropriate to empirical sciences. It is not always possible nor desirable to control strictly the language used in the sciences. That complexity which is an integral part of scientific writing, for example causal and implicative propositions and the relational sentences in which they are stated, must at least be recognized.

According to theories of transformational grammar, there are a variety of grammatical transformations that can increase the complexity of sentences at the surface level as well as at the deep structure or meaning level. Dawkins (1975) lists six processes that produce the variety and complexity among sentences in the English language: arrangement, rearrangement, addition, deletion, substitution, and agreement. The first four of these processes, arrangement, rearrangement, addition, and deletion, are used most frequently in the language patterns of scientific writing.

The Process of Arrangement: Negative Expansions

The process of arrangement refers to the order of elements in simple sentences. Included in the arrangement process are "negative expansions," that is, the expanding of any main verb with a negative 'not' or 'n't.' Negatives occur frequently and are grammatically simple, but they do contribute to syntactic complexity and may create difficulties in reading comprehension.

Negatives used in hypothetico-deductive statements require the

use of different, more complex forms of logical reasoning. The negative 'not' may be used in a variety of ways in statements resulting in varying complexities. For example, one or two negative expansion processes may be added to the basic sentence:

If air is heated, then it will rise.

If air is not heated, then it will remain stable.

If air is not heated, then it will not rise.

The Process of Rearrangement: Question Transformation and 'If-Then' Inversion

Rearrangement includes a number of transformations which retain the elements of a simple sentence but change the form of the sentence. They include the question transformation and changes in word arrangement.

Because of the extra process that goes into a rearranged sentence, we can hypothesize that it is more difficult than the simple sentence from which it is derived. The analysis and processing required to answer a question may indeed be an additional difficulty, for a question refers to information in linguistic form (Bormuth, 1969).

Whenever the expected word order is not followed, we can hypothesize that the rearrangement adds a degree of difficulty. For example, when the 'if-then' arrangement in a conditional sentence is violated, we can assume that it gives the reader a somewhat harder task, for the violation of one's expectations or predictions may interfere with the processing of the entire sentence. 'If-then' inversions in sentences are infrequent and therefore not highly predictable. Such refocusing may well be more difficult for the young

reader to process.

The Process of Addition

Addition as described by Dawkins is the essential process in the production of complex sentences.

> Addition may not be the only process in the formation of complex sentences, for when we add sentences the syntax may also involve the processes of rearrangement, substitution, or deletion (p. 12).

The process of addition is most commonly accomplished by using connectives, particularly coordinating and subordinating conjunctions, to link and relate ideas in compound and complex sentences. Although coordinating conjunctions (and, but, or, so, for, yet) are considered less difficult than subordinating conjunctions, all coordinating conjunctions are more difficult to process than 'and.' Katz and Brent (1968) found that young children had difficulty with the adversative 'but.'

Robertson's (1966) study showed a significant relationship between a child's understanding of connectives and reading comprehension test scores. Although there was an increase in understanding of connectives from grades four to six, Robertson found that certain connectives, including 'however,' 'thus,' and 'although' were at the lowest comprehension levels of the total sample. These particular language constructs are not usually used by children and are seldom found in their reading materials.

The process of addition, according to Dawkins (1975), may also involve the adverbial function by means of words (adverbs), phrases (usually prepositional phrases), or clauses. Adverbial phrases are

structurally more complex than simple adverbs. Different types of adverbials vary in difficulty for children. Vygotsky (1962) found causality to be more difficult in meaning than time. Similarly, conditionality may well be more difficult than simple causality.

Adverbial clauses are subordinate clauses which contribute the additional complexity of a whole sentence, which is what a clause is essentially. They begin with subordinate conjunctions 'after,' 'because,' 'if,' 'since,' 'where,' 'when,' all of which involve differences in meaning.

Adverbial clauses would be expected to be more difficult than words and phrases simply on the basis of their length and structure. But there is evidence (Vygotsky, 1962; Robertson, 1966; Katz and Brent, 1968) that some of the difficulty would lie in the meanings of some of the subordinate conjunctions. Research does not offer definitive answers on the relative complexity of, for example, 'if' as opposed to 'because,' but it may be safe to assume that conditionality is more difficult than causality. Among the most difficult test items in Robertson's study were longer clauses than those students commonly use which included adverb clauses of condition or concession.

Because students also had some difficulties in conjoining ideas with 'and' and 'but,' Robertson postulated that children may have difficulty holding information units in short term memory in reading comprehension. Dawkins (1975) also raises "the question of distance between subject and verb resolution" (p. 29). The addition of a series of qualifying words or phrases that increases this distance would likely make the sentence more difficult. Similarly, the addition

of words, phrases and clauses between the antecedent and consequent in a conditional sentence increases the burden on memory and complicates the logical process. The role of memory in reading comprehension was studied further by Jackson (1970).

The majority of sentences in print beyond the primer level involve multiple additions, that is, addition of more than two sentences. The more additions to a sentence, the greater the difficulty. Moreover, rearrangement and deletion processes are usually also present in syntax that involves additions, contributing additional complexity. Dawkins (1975) offers this summary of the effect of the processes of addition on syntactic complexity:

> Until it has been proven otherwise, we can assume that each additional process adds an element of complexity. And when a particular structure is infrequent, we have another indicator of difficulty. Finally, we suggested that the subject-verb relationship is basic in syntactical meaning, so when that relationship has been made less clear than usual (by the operation of the two or by a possible ambiguity), then still another element of difficulty has been added to a sentence (p. 24).

<u>The Process of Deletion: 'Then' Deletion</u>

Deletion transformations remove certain words or parts of sentences according to rules of grammar without substantially changing meaning. Although deletion makes a sentence more compact, it reduces clues to meaning thereby adding to sentence difficulty. For example, the word 'then' which serves to introduce the consequent may be removed from a conditional sentence:

If the air is heated <u>then</u> it will rise.

If the air is heated it will rise.

In this example the reader must supply the missing 'then' to the second

sentence when interpreting it.

Deletions may cause difficulty when children must contribute information to a sentence in order to comprehend its meaning. Children in their everyday usage do not omit 'then' from their speech or writing. O'Donnell, Griffin and Norris (1967) found that structures produced by deletion transformations appear relatively late in children's oral language.

Fagan (1969), using transformational grammar, investigated the relationship between reading comprehension and the number and types of transformations in basal readers used by children in the upper elementary grades. He found deletion to be among the most difficult transformations for children to process. Cosens (1974) studied the effect of deletion produced structures on the word identification and comprehension of children in grades one and two. She found that the presence of deletion transformations was negatively related to sentence comprehension.

The implied 'then' is a structure which lends a smoothness and certain sophistication to adult language. Adults, therefore, may not experience difficulty with 'then' deletion, but children conceivably would. Research has shown that children comprehend best those language structures which are closest to their usage. Since children commonly retain 'then' in conditional statements, it is possible that deletion of 'then,' as foreign to children's language, would create problems in comprehension.

Sentence patterns which are the result of any of the above grammatical processes will likely affect the degree of understanding

which a child derives from what he is given to read. If a child is to understand fully what he reads, he must be able to analyze the written language patterns in which the information is conveyed. In order to decide what structures to teach children to analyze, it is first necessary to know the types of structures used in books written for children.

The Relationship of Language and Thinking

Language and thinking are so interrelated that they must be considered together. Language is the main vehicle for advanced thinking and reasoning. It is generally accepted that language also has a certain amount of control over thinking. Conditional ideas evoking hypotheses and possibilities, for example, are rooted in the conditional sentence. According to Thomson (1959),

> Without the sentence, considered as a conditioning and generalizing device, elementary reasoning could not be carried out with efficiency and clarity (p. 175).

Relationships are stated in sentences, and cumulative abstract thinking requires the use of linguistic structures.

Development of Language and Thinking

As children mature they gradually acquire the language structures that carry the various kinds of thought. Loban (1963) followed the language development of eleven kindergarten classes until they had completed sixth grade. He found that as children become older and more effective in the use of language, their language tends to express more tentativeness, more supposition, and more conditionality.

Two of the foremost developmental psychologists of this century, Piaget and Vygotsky, agree that children may use expressions of propositional thinking expressing logical relations long before they fully grasp the logic, or the "structures of meaning corresponding to these syntactic forms" (Vygotsky, 1962, p. 20). According to Piaget (1962) children do not grasp completely the logic of relations expressed by connectives until they are well into high school. The use and development of language nevertheless is important to growth in the ability to think and reason. Although Vygotsky and Piaget agree on the necessity of language to cognition, they hold somewhat divergent positions on the subject of the relationship between language and thinking in a child's development.

Piaget regards language as an outside agent in the child's developing thought that comes to serve him by translating his personal symbols into meanings held by society. The child's use of speech and language does not substantially affect the development of personal symbolic structures.

Although the symbolizing and verbalizing occur almost simultaneously, Piaget seems to view them as separate operations. Unless the teacher begins with the child's spontaneous structures, adult language is likely to confuse the child's thinking or allow him to settle for a verbalized statement of an idea without knowing what it means.

In contrast to Piaget's emphasis on the structuring of thought symbols by observation and manipulation of the environment prior to the injection of language, Vygotsky's emphasis is on the language of

the children and the adult teacher in the creation of thought. The early interaction between the child's complexes (similar to Piaget's structures or schemata) and the language of the environment is crucial.

According to Vygotsky, the child's egocentric speech becomes the inner speech that is the shorthand of thinking. This speech is not accompanying thought; it "serves mental orientation and conscious understanding." Inner speech is thought connected with words, although "Inner speech is not the interior aspect of external speech—it is a function in itself" (1962, p. 133). Vygotsky views "pure thought" as nonlingual and conceived all at once, but he places inner speech just prior to the emergence of a "pure meaning" and sees it as the first step toward preparing a thought for communication. He concedes that "Words play a central part . . . in the development of thought" (1962, p. 153).

The Grammar of the Word 'If'

Structural linguists such as Fries (1952) distinguish between lexical and grammatical words in the English language. Lexical words are considered to be the "content" words of the language, referring to things, actions and qualities in the "real" world. The grammatical words do not refer to the "real" world, but are "function" words such as 'may,' 'the,' and 'if' which serve to provide the sentence structure or framework for the lexical words (Wardhaugh, 1969). Linguists concede that the distinction between lexical and grammatical words is not clear-cut, but it is useful, and points to the importance of the grammatical meanings in sentences.

Lefevre (1970) divides all English words into two categories which he labels "reference" words (analogous to lexical or "content" words), and "structure" words (analogous to grammatical or "function" words). Structure words, according to Lefevre, mark off structural elements within sentences, and also signal relationships between sentences as well as among sentences in extended discourse.

Lefevre states that there are approximately 300 "structure" or "empty" words which have no referents in the real world outside the language system. These words make up nearly half the Dolch list of the 220 most commonly used words, and are among the first that children learn to read. Although they are easy to read, their abstract nature may make them difficult to understand.

> Because structure words identify many syntactical elements, and also signal the structural and semantic relationships among the elements, they are both meaningful and rather abstract (Lefevre, 1970, p. 198).

Lefevre groups structure words into five major sets of "markers," or sets of words that identify and mark off main syntactical elements:

1. Noun markers (articles and other words that serve a similar function).
2. Verb markers (auxiliaries, modals and others that serve a similar function).
3. Phrase markers (single prepositions as well as groups).
4. Clause markers (all conjunctions, words, and groups that serve similar functions).
5. Question markers (words that start questions).

Clause markers, according to Lefevre (1970, p. 217), include

three main groups: coordinating conjunctions, subordinating conjunctions, and sentence connectors. He applies the name "correlative conjunctions" to coordinate or subordinate conjunctions that work together in pairs. Examples of correlative conjunctions, which mark clauses as well as other syntactic structures, are: 'either . . . or,' 'neither . . . nor,' 'when . . . then,' and 'if . . . then.'

In structural terms, the word 'if' is a subordinate clause marker which may also be called a sentence "connector" or "connective" indicating a conditional connection (Gleason, 1965, p. 342). According to Gleason, the English language has a great variety of clause connectors having greatly varying patterns of use. This feature gives the language great flexibility, particularly in written form.

> It permits the signaling of complex interclause relationships with great precision when this is desired, or more loosely when that is preferred (p. 344).

Inherent in this flexibility, however, is possible confusion over intended meaning. Gleason emphasizes that it is necessary to distinguish between grammatical relationships and logical relationships. For example, in the sentence 'If air is heated it will rise,' 'if air is heated' is connected somewhat loosely grammatically and structurally to the main clause, but it adds a precise logical relationship and changes the meaning of the sentence substantially. Cautions Gleason:

> Logical coordination and subordination have no necessary connection with grammatical coordination and subordination—this is an important fact about English (p. 334).

Differential Uses of the Word 'If'

It is obvious that lexical words have multiple meanings in the English language. But function words such as 'if' also have a variety of meanings and differential uses, and these require the reader to make decisions about the precise meaning the word has in a particular context.

The Intermediate Dictionary (Gage, 1963, p. 441) lists four meanings of the conjunction 'if': (1) supposing that or in case that; (2) on condition that; (3) whether, and (4) although or even though (informal).

Writers and educators alike make the assumption that grammatical words have a single meaning. As a result, they ignore the decision making process that must take place to determine the correct meaning in a particular context and the difficulties this may entail.

Role of Relational Words in Reading Comprehension and Readability

Many studies have found that the critical words in reading comprehension are words which serve to relate ideas. These relational words are a class of function or structure words which can be called "logical signs" (Fodor and Katz, 1964), or "logical operators" (Rawson, 1965; 1969). Difficulties in comprehension are likely to result when children neglect the logical function of words such as 'if.'

Although the words which serve as logical operators (for example, 'if') are easy to read, they may be the most difficult for children to understand because they have no referents in the concrete world. They have meaning in logical relationships, and their

grammatical function is to relate elements between and among sentences.

Writers of children's textbooks have long been aware of problems associated with lexical word meanings, and as a result have attempted to control concepts and vocabulary at various grade levels. They have been much less aware, however, of problems inherent in structural meanings and logical functions of "simple" relational words. The logical complexity of related statements may be much greater than the syntactical complexity of the sentences in which they are conveyed, at least for children.

The Logic of the Word 'If'

Logic may be defined as a branch of thought or reasoning that is concerned with the objective relation between evidence and conclusion (Keene, 1961; Ennis, 1965; Salmon, 1973). Statements of evidence and conclusion are commonly referred to as an "argument." A logical argument consists of one or more statements of evidence and one statement which is the conclusion. The statements of evidence are called "premises." Premises are stated as facts, and are offered as evidence for the conclusion.

The Role of Logic in Science

Another function of logic, according to Salmon (1973), has to do with thinking or reasoning. When people reason, they make inferences. These inferences can be used as premises to justify a conclusion. Much of our scientific knowledge is the result of making inferences.

For example, until very recently, scientists believed that

Venus was a very wet planet as a result of receiving a great deal of almost ceaseless rain. Scientists had not seen rain falling on Venus, but they did see the planet shrouded in thick clouds, and <u>inferred</u> that it was subjected to heavy rains. On the basis of the factual data available, <u>i.e</u>. Venus is surrounded by thick clouds, scientists were able, by means of inductive reasoning, to infer that there was a great deal of rain falling on Venus and that Venus was a very wet planet.

This conclusion was recently proved factually incorrect by information relayed by sophisticated equipment which landed on Venus. The <u>logic</u> of the original argument, however, is correct. The scientific generalization (rain on Venus) has an inductive relation to its premise based on observational evidence (clouds surrounding Venus). The logical correctness or logical truth (often called "validity") of an argument does not depend upon the factual truth of premises or conclusion, but on the necessary truth of the relation between premises and conclusion. In the same manner, the validity of an inference is "independent of the truth of the beliefs or opinions which constitute its evidence" (Salmon, 1973, p. 9).

The Role of Language in Scientific Logic

Fodor and Katz (1964) see the role of logic in empirical science as that of furnishing instruments for deduction, "for the transformation of formulations of factual, contingent knowledge" (p. 420). They contend that an analysis of language and its application must also be an integral part of an analysis of theoretical procedures in science. The material on which the scientist works in

his theoretical activities, including reports of observations, scientific laws and theories, and predictions, are formulated in language.

The making of inferences is also dependent upon language as a vehicle. According to Keene (1961),

> . . . inferring is a different kind of performance from stating . . . inferring is a performance having as its components the making of successive statements. When we infer, we make a step from one or more statements to another. The "direction" in which the step is being made is by means of such words as "therefore" and "then" (p. 67).

Thus, we use a sequence of statements for a single inference. When we infer, there are at least two sentences with which statements could be made: at least one statement from which we are inferring, and one statement to which we are inferring.

Inferences may then be appraised as valid (correctly reasoned) or invalid (incorrectly reasoned) by reference to logical rules. In considering the correctness of an inference it is necessary to examine the sentences used in the argument. The correctness of the reasoning depends upon the correctness of relationships among the sentences used.

Inductive and Deductive Reasoning

Philosophers have delineated many types of logical reasoning. Two major types used in empirical sciences are induction and deduction.

Inductive reasoning involves inferring on the basis of premises (facts or observational evidence) to reach a conclusion not present or implied in the premises. Induction arrives at inferences by going beyond available data. Scientific generalizations are conclusions reached as a result of inductive reasoning from supporting

observational evidence.

e.g. Every planet that has ever been observed has an orbit.

Therefore, every planet has an orbit.

Deductive reasoning, on the other hand, is firmly rooted in data stated or implied in the premises. It involves reaching a conclusion only on the basis of data (facts or inferences) in the premises. All of the information in the conclusion is already contained in the premises. If all of the premises are true, then the conclusion must be true. The logic of mathematics is deductive. The following is an example of deductive reasoning in science:

Every planet has an orbit.

Pluto is a planet.

Therefore, Pluto has an orbit.

Salmon (1973) offers this summary on the different functions of deductive and inductive arguments in reasoning:

> The deductive argument is designed to make explicit the content of the premises; the inductive argument is designed to extend the range of our knowledge (p. 15).

Conditional Logic

Deductive logic is regarded as central in critical thinking by Ennis (1965), who states that there are three recognized types of deductive logic: sentence, class logic, and ordinal logic. He defines sentence logic as

> . . . being concerned with arguments in which the basic units are sentences. That is, distinct sentences, often connected or modified by such logical connectives as 'if,' 'only if,' 'then,' 'and,' 'or,' 'not,' and 'both' . . . (p. II-4).

A sentence which contains the conditional 'if' may be called

a conditional sentence. Conditional logic deals with statements containing the word 'if' which introduces conditions upon which the truth of the rest of the statement containing them depends. The part of the sentence introduced by the word 'if' is called the "antecedent." It contains the premise or premises stated as a condition for what is to follow. The rest of the sentence, which may be introduced by the word 'then' is called the "consequent."

The antecedents and consequents of conditional sentences are propositions, and as such, are statements in their own right. A conditional sentence expresses the relationship between the propositions, or between the antecedent and consequent, in a specific form. The connectives 'if — then' place two statements, or propositions, in definite relation to each other.

Logical Forms of Conditional Statements

Logicians have worked out specific forms, or laws, of conditional statements. There are three chief forms of conditional reasoning in deductive logic (Salmon, 1973):

1. Modus Ponens (affirming the antecedent).
2. Modus Tollens (denying the consequent).
3. Transitivity.

The law of modus ponens, or affirming the antecedent, takes the form

If p, then q.	e.g.	If an animal is a dog, then it has a tail.
p.		Sam is a dog.
Therefore q.		Therefore Sam has a tail.

The first premise is a conditional statement, and the second premise

affirms or asserts the antecedent of this conditional. The conclusion of the argument is the consequent of the first premise, therefore, the argument is valid.

This 'if-then' relation, however, is not symmetric (Ennis, 1965; Salmon, 1973). An argument which takes the following form is considered to be invalid because the affirmation of the consequent does not imply the affirmation of the antecedent.

If p, then q.	e.g.	If an animal is a dog, then it has a tail.
Therefore, if q,		Therefore, if Sam has a tail,
Then p.		Then Sam is a dog.
(Invalid)		(Sam may be a cat.)

Similarly, the denial of the antecedent does not imply the denial of the consequent.

If p, then q.	e.g.	If an animal is a dog, then it has a tail.
Not p.		Sam is not a dog.
Therefore not q.		Therefore Sam does not have a tail.
(Invalid)		(Sam may be a cat with a tail.)

The law of modus tollens, or denying the consequent, may be expressed in the following manner:

If p, then q.	e.g.	If an animal is a dog, then it has a tail.
Not q.		Sam does not have a tail.
Therefore not p.		Therefore Sam is not a dog.

The first premise is a conditional statement, and the second premise is the denial or negation of the consequent of that conditional.

Another valid form of denying the consequent is:

If p, then not q.	*e.g.*	If an animal is a dog, then it does not have wings.
Therefore, if q,		Therefore, if Polly has wings,
Then not p.		Then she is not a dog.

The consequent of the first premise is a negative statement, so the second premise, which is its denial, is affirmative.

The *principle of transitivity* takes the form

If p, then q.	*e.g.*	If an animal is a mammal, then it is warm-blooded.
If q, then r.		If it is warm-blooded, then it produces milk for offspring.
Therefore, if p,		Therefore, if an animal is a mammal,
Then r.		Then it produces milk for offspring.

The principle states that if p implies q, and q implies r, then p implies r. Here the 'if-then' relationship is transitive.

Logicians have formulated rules and principles of reasoning, but they do not attempt to describe or explain the mental processes that occur when people think, infer, or reason. That is the concern of psychology.

Logic, Psychology, and Development of Logical Reasoning

The Role of Logic in Developmental Psychology

Piaget and his associates applied logical techniques to their study of thought structures found at different levels of intellectual development. They found that the "algebra of logic" helped them to specify psychological structures. In his introduction to Piaget's *Logic and Psychology* (1957), W. May states:

> The psychologist for his part welcomes the qualitative character of logic, since it facilitates the analysis of the actual structures underlying intellectual operations, as contrasted with the quantitative treatment of their behavioural outcome. Most "tests" of intelligence measure the latter, but our real problem is to discover the actual operational mechanisms which govern such behaviour, and not simply to measure it (p. xviii).

Piaget (1957) uses the term "operationalism" and describes it as providing real ground for the meeting of logic and psychology. He defines "operations" as "actual psychological activities" and states that a system of operations is what all effective knowledge is based on (p. 7). He states further that

> Psychologically, operations are actions which are internalizable, reversible, and coordinated into systems characterized by laws which apply to the system as a whole. They are actions, since they are carried out on objects before being performed on symbols. They are internalizable, since they can also be carried out in thought without losing their original character of actions. They are reversible as against simple actions which are irreversible (p. 8).

Piaget argues that experience or "empirical truths" cannot be considered as separate from logical relationships. He states that "experience cannot be interpreted in abstraction from the conceptual and logical apparatus which makes such an interpretation possible" (p. 4). He also maintains that logical relationships never appear as a simple system of linguistic or symbolic expressions, but always imply a group of operations acting as a whole. This is true throughout the logical development of children as well as in maturity.

Logic, in fact, appears relatively late in the thinking of children. According to Piaget, the first operations dealing with classes occur between 7 and 8, and those concerned with propositions between 11 and 12, on the average. From the point of view of

developmental psychology, the criterion for the appearance of operational systems is the construction of "invariants" or concepts of conservation. Piaget (1957) conceives of conservation as the result of operational reversibility.

Piaget has defined four main stages in the construction of operations, or logical development. These extend over the period from birth to maturity. By means of these stages, Piaget and his associates attempt to describe the continuous cognitive development, leading from the infant's initial sensorimotor actions to the most abstract mental operations of the adult.

Piaget's Stages of Intellectual Development

Piaget maintains that the origin of all intellectual operations is to be found in the initial stage of development which is characterized by sensorimotor actions and intelligence.

At about the age of two years a second period begins, the onset of which is

> . . . marked by the formation of the symbolic or semiotic function. This enables us to represent objects or events that are not at the moment perceptible by evoking them through the agency of symbols or differentiated signs (Piaget, 1970, pp. 30-31).

Piaget and Vygotsky agree that the highest example of this process is language itself. This period of intelligent thought, however, in Piaget's terms, remains "preoperational."

At about seven or eight years of age a third period begins which sees the formation of mental operations, including the linking and dissociation of classes and the linking of relations. These mental operations, however, "are still applied solely to objects, not to

hypotheses set out verbally in the form of propositions" (Piaget, 1970, p. 32). Because all these initial operations are still close to and dependent on the actions which give rise to them, they are termed "concrete" as opposed to "abstract."

The beginning of abstract reasoning heralds the onset of a fourth and final stage of cognitive growth at about eleven or twelve years of age. Piaget (1970) describes the thinking at this stage thus:

> This period is characterized in general by the conquest of a new mode of reasoning, one that is no longer limited exclusively to dealing with objects or directly representable realities, but also employs "hypotheses," in other words, propositions from which it is possible to draw logical conclusions without it being necessary to make decisions about their truth or falsity before examining the result of their implications. We are thus seeing the formation of new operations which we term "propositional," in addition to the earlier concrete operations: implications ("if . . . then"), disjunction ("either . . . or"), incompatibilities, conjunctions, etc. (p. 33).

This period of formal propositional or "abstract" reasoning is given the name "formal operations" by Piaget.

Logical Reasoning in the Formal Operational Stage

In his book The Developmental Psychology of Jean Piaget (1963), Flavell states that "The most important general property of formal operational thought, the one from which Piaget derives all others . . . concerns the real versus the possible" (p. 204). It is the ability to deal with the possible rather than just the real that supposedly is unique to the formal operational period.

Childish reasoning between the years seven to eight and eleven to twelve will be reasoning based on direct observation or experience, and connected with actual belief. Formal reasoning, on the other hand,

connects assumptions or propositions in which one does not necessarily believe but which one admits in order to see what consequences they will lead to (Piaget, 1928).

More specifically Piaget (1950) says that the formal operational thinker is able to reason

> . . . on the basis of assumptions which have no necessary relation to reality or to the subject's beliefs. . . . He relies on the necessary validity of an inference as opposed to agreement of the conclusions with experience (p. 148).

Piaget maintains that propositional reasoning, including conditional reasoning, is not possible until age eleven or twelve. The child at the concrete level of operations (from seven or eight to eleven or twelve years) cannot handle propositional logic (1958, p. 1).

In 1958 Piaget introduced two periods in formal operations, the first running from eleven or twelve years to fourteen or fifteen years, and the second from fourteen or fifteen years onward. He holds that it is not until the second period that the child thinks in terms of necessity of relations instead of constancy (p. 11), and that the full grasp of the concept "all other things being equal" is attained (p. 43). It appears that Piaget believes a child is not ready to reason by means of propositional logic until he is fourteen or fifteen years old, on the average.

That Piaget (1950) considers conditionals to be central to propositional logic is seen in the following quotation which, in referring to implications between propositions, is referring to conditionals:

> Formal operations, therefore, consist essentially of "implications" (in the narrow sense of the word) and "contradictions" established between propositions which

themselves express classifications, seriations, etc. (p. 149).

Children's Conditional Logic Reasoning Abilities and Effectiveness of Teaching Conditional Logic

Ennis's (1965) study of the role played by deductive logic in the critical thinking of adolescents was based partly on the work of Piaget. The age range of children used by Ennis was roughly ten to eighteen, which corresponds approximately to that of Piaget's formal operational period.

Deductive logic is regarded by Ennis to be a central part of critical thinking. He states that he chose to study conditional logic specifically because

> . . . the if-then relationship is fundamental in all logic and because an understanding of conditionals together with conjunction and negation enables one to do other types of sentence reasoning (1965, p. II-8).

Ennis uses the term "sentence" in place of the term "proposition" and "propositional" used by logicians.

To test adolescents' knowledge of conditional reasoning, Ennis and his colleagues developed <u>The Cornell Conditional-Reasoning Test</u>, a 72-item multiple choice test covering twelve principles or combination of principles of conditional logic. The list of principles or combinations embodied by the items are given in the Appendix as they are presented by Ennis (1965) on pages II-10 and II-11 of his report. Subjects of above average intelligence were selected from classes in grades 5, 7, 9 and 11, and divided into two groups. One group was taught logic intensively for a short period of time to determine the effectiveness of teaching logical principles at various

grade levels. A comparable group of students received no instruction in logic. These subjects were used primarily for data on the natural-cultural development of knowledge and logic.

One research question in Ennis's study, whether there is actually a development of logical ability as children grow older, received a definite affirmative answer and supported Piaget's theory. Another question asked whether conditional logic was mastered by age eleven or twelve, which corresponds roughly to children in sixth grade. If conditional reasoning is mastered by this age, then it should be mastered by some of Ennis's subjects in grade five, and by most in grade seven. Results of the investigation suggested

> . . . that there is mastery of some of the principles by some of the people of age 11-12, but rarely (if ever) mastery of all of the basic principles and frequent non-mastery of most of them (p. V-24).

Ennis also noted that conditional reasoning was not mastered by students in grade eleven either, although there was considerable improvement from grade five to grade eleven.

The results of the teaching of conditional reasoning by Ennis's team indicated that there was very little learning in grades five, seven and nine, but that there was a vast improvement in grade eleven. Ennis concluded that there is not much point in trying to teach conditional logic below grade nine.

In contrast to the generally negative results of teaching conditional reasoning, Ennis found that for class reasoning there were small amounts of improvement from grade six onward. He suggests the reason for this disparity may be the lack of children's understanding of the logical meaning of the word 'if':

> One possible explanation of the marked difference between conditional and class reasoning is that the major learning that accounts for the vast improvement in conditional reasoning was the learning of the sufficient-condition meaning of the word 'if,' which has no analogue in class reasoning. One difficulty with this explanation is that it leaves one wondering why the meaning of this word was not effectively taught in grades 5, 7, and 9 (1967, p. VI-40).

If language and thinking ability are intimately related, then teaching the vocabulary of conditional reasoning, specifically the meanings of the word 'if,' should result in increased powers of logical reasoning.

A later study by Ennis and his colleagues (1969), reported by Lowerre and Scandura (1973), achieved varying degrees of success in attempting to teach conditional logical inference rules to children in grade three. Results of other investigations in which researchers attempted to teach logic to elementary school children reported in the same article indicated that all were successful to some extent in improving children's scores on a general test of logic. None of the studies, however, systematically combined teaching and diagnostic testing. There was no testing before teaching to determine exactly which rules of logic children knew and the contexts in which they could use them.

To avoid the limitations of earlier studies, Lowerre and Scandura developed highly individualized prototype materials for teaching rules of logic using "systematic dimensional analysis." It is intended for use in diagnostic testing and teaching with elementary school children. Included is a pretest for each rule to determine each child's ability to use it in a variety of reading contexts. Initial instruction is then based on the child's pretest

performance, and each rule presented in more difficult settings after mastery has been attained in simpler settings. Finally, post-test scores indicate the contexts in which each rule can be used by each child.

The Role of Education in Fostering Logical Reasoning

Piaget believes that the goal of education is to present opportunities for a child to invent and discover. He warns

> When we teach too fast, we keep the child from inventing and discovering himself. Teaching means creating situations where structures can be discovered; it does not mean transmitting structures which may be assimilated at nothing other than a verbal level (1964, p. 3).

In his later statements about education, Piaget (1970) maintains that the question of the child's logic is crucial where intellectual education is concerned. Equally important for education is knowledge of the conceptual sphere, which according to Piaget, involves at least three essential domains in the logical structure of thought: formal principles, the structure of classes, and the structure of relations (p. 163).

Experiments performed by Piaget and his associate Inhelder (1958) indicate that normally before the age of ten or eleven the child is not capable of any kind of reasoning, that is, purely verbal or hypothetico-deductive symbolic logic. According to Piaget (1970), the difference between the child's thought and formal reasoning is most glaring in the field of relational logic where he tends to remain bound by idiosyncratic thought:

> In the child, however, relations certainly appear to be of a primitive kind in the genetic order; they are at work as early

> as the sensorimotor phase; but their manipulation on the level of reflexive intelligence remains difficult for a long time: individual thought begins, in effect, by judging everything from its own point of view—and by regarding as absolute characteristics that it will later come to recognize as being relative (pp. 165-166).

Piaget regards cognitive growth as continuous, and which necessarily passes through all four stages in order. He believes that intellectual development is largely dependent on an internal maturation independent of the external environment, but concedes the "possibility of influencing and accelerating that development" (1970, p. 170).

The ages at which the various stages occur are nothing more than averages, and all persons do not attain the highest level even in adulthood. Furthermore, there are overlaps in logical development when one passes from one stage or task to another. Above all, Piaget stresses that "each stage of development is characterized much less by a fixed thought content than by a certain power, a certain potential activity" depending on the child's environment (1970, p. 171).

Both Piaget and Vygotsky postulated and described several stages in the development of thinking which correspond roughly. Neither Piaget's "stages in the growth of thought" nor Vygotsky's "stages of concept development" are distinct periods or ages in a child's life. Rather, these stages are descriptions of a style of thinking which the child uses in coming to terms with his environment. When the child has explored a way of thinking sufficiently to have developed the "schemata" (Piaget) or the "complexes" (Vygotsky) that will support the next mode of thinking, he moves on. Thought structures are built that will support new relationships and connections.

There is general agreement between Piaget and Vygotsky that children will move from one stage of complexity to the next depending on the richness of their experiences, quality of dialogue with others, and concomitant neurological development.

Summary

This chapter has attempted to justify the undertaking of the present investigation.

Teachers of content subjects have long been aware that children experience difficulties getting information from textbooks in spite of readability controls. Difficulties in reading comprehension are often the result of failure to understand the relations expressed within a sentence and between sentences. As the relations and the sentences in which they are communicated become more unfamiliar and complex in textbooks beyond the primary grades, these difficulties are likely to increase as children progress into the middle grades.

Science textbooks make special use of conditional relations by means of 'if-then' statements. Such hypothetico-deductive statements demand ability to reason according to rules of propositional logic to ensure full comprehension. Formal propositional logic, and conditional logic in particular, appears relatively late in children's intellectual development.

For these reasons there is need to know the types of conditional logic to which pupils are exposed in the textbooks they are expected to read. It is also necessary to be aware of grammatical processes in conditional sentences which may complicate logic as well

as syntax, and thus present possible additional hindrances to their comprehensibility.

Chapter 3

DESIGN OF THE STUDY

Because reasoning ability using conditional logic is just beginning to develop among students in sixth grade, it is necessary to know the extent to which children are exposed to this type of reasoning in their textbooks. There is also need to know the grammar and logic of 'if' as it is actually used in their textbooks. Multiple meanings of 'if' and the differential grammatical uses of this word must be recognized. It is also necessary to be aware of the uses of 'if' according to principles of logic. Finally, there is need to be cognizant of various types of syntactic complexity to which a simple conditional sentence may be subjected. Such complexities may compound difficulties in the logical as well as grammatical structure of the sentence. Having isolated sentences containing 'if,' further analysis will determine some of the grammatical and logical complexities present in the sentences.

To investigate the frequency, distribution and complexities of sentences containing 'if,' a number of children's textbooks in science were selected and analyzed.

This chapter will present rationales for the choice of grade and textbooks, and will describe the method of sample selection. The chapter will conclude with a table giving an initial analysis of the frequency and distribution of sentences containing 'if' in the textbooks analyzed.

Analysis of Textbooks

Rationale for Choice of Grade Level

Children in grade six are usually 11 to 12 years of age, the time period which marks the onset of abstract reasoning powers and ability to do propositional logic. These abilities, however are just beginning at this age and grade level, and studies have shown that the majority of children are unable to deal with logical reasoning without specific and systematic instruction. Because children in grade six are capable of independently decoding material written for them, they are usually required to read and to acquire information from their textbooks without assistance.

Rationale for Analysis of Science Textbooks

Science textbooks are a main source of information about science beyond the primary grades. Teachers find, however, that textbooks are too difficult for children even when vocabulary and concept load have been controlled. The understanding of scientific concepts and processes involves logical reasoning and is dependent on full comprehension in reading of the relationships expressed in print.

Science textbooks make special use of conditional relations. The 'if-then' relationship is fundamental to much of logical reasoning. An understanding of the conditional 'if' and ability to do elementary conditional reasoning is a prerequisite to most hypothetico-deductive reasoning in science.

The importance of the 'if-then' sentence in science is acknowledged in the textbook Concepts in Science 6 (Brandwein et al., 1966).

However, it is not until the end of the book, on page 421, that the reader is alerted to its significance:

> Notice the IF-THEN type of sentence. This kind of statement is one way in which you make a kind of prediction. If a first condition is true, then the other condition, which depends on the first, may also be true. This kind of statement is called a hypothesis, or working idea.

Selection of Science Textbooks

The Curriculum Branch of the Department of Education for the Province of Alberta recommends three series of science textbooks to be used as resource material in classrooms from grades one through six. Pupils are expected to make extensive use of these authorized textbooks in the upper elementary grades. This study includes the following three textbooks at the grade six level:

Barnard, J. D., Celia Stendler, and Benjamin Spock. *Science for Tomorrow's World*. New York: Macmillan, 1966.

Brandwein, P. F. *et al*. *Concepts in Science*. New York: Harcourt, Brace and World, 1966.

Fischler, A. S., L. F. Lowery, and S. S. Blanc. *Science a Modern Approach*. New York: Holt, Rinehart and Winston, 1966.

Analysis of Sentences Containing 'If'

Method of Sample Selection

The sentences selected for analysis include every sentence containing 'if' in all three textbooks. Every 'if' sentence was recorded on a separate file card. Each data card included the complete sentence, the page number, and the title of the textbook from which the sentence was obtained. The total sentence sample was then

subjected to a variety of counts.

Initial Analysis of Number of Sentences Containing 'If'

The frequency and distribution of all sentences containing 'if' by textbook series is shown in Table 3.1 and provides the basis for the more detailed analysis in Chapter 4.

Table 3.1

Total Number of Sentences Containing 'If' in the Three Science Textbooks

	Number	Percentage
Concepts in Science	240	34.985
Science a Modern Approach	266	38.776
Science for Tomorrow's World	180	26.239
Total	686	100

Table 3.1 shows that there is a total of 686 sentences containing 'if' in the three textbooks. Science a Modern Approach has the greatest number of these sentences, 266, followed by Concepts in Science with 240. Science for Tomorrow's World has the fewest sentences containing 'if,' 180.

Summary

Three science textbooks at the grade six level recommended for use in Alberta schools by the Department of Education were analyzed for sentences containing 'if.' A total of 686 sentences were found

in the three textbooks. These sentences were recorded for further analysis in the next chapter.

Chapter 4

ANALYSIS OF TEXTBOOK FINDINGS

If sentences containing 'if' which include statements with 'if-then' propositions are difficult for grade six pupils to understand, the differences in the number of such sentences in textbooks may be one indication of the relative difficulty of the individual textbooks. However, there are additional grammatical, syntactical and logical factors in the sentences which must also be considered.

Frequency and Distribution of 'If' in Sample

Of the total number of sentences which contain 'if,' 686 (Table 3.1, p. 53), nine use 'if' twice, yielding a total of 695 times 'if' is actually present in sentences in the three textbooks.

> e.g. If light consisted of tiny particles they would surely collide if two beams of light were shined into each other (Science a Modern Approach, p. 332).

Table 4.1 shows the frequency and distribution of sentences containing 'if' twice in the textbooks. Table 4.2 shows the total number of times 'if' is used in sentences in the three science textbooks.

Differential Uses of 'If' According to Meaning

The Intermediate Dictionary (Gage, 1963, p. 441) gives four meanings of the conjunction 'if':

1. supposing that, in case that:
   e.g. If you are going, leave now.

Table 4.1

Number of Sentences Containing 'If' Twice

	Number
Concepts in Science	4
Science a Modern Approach	3
Science for Tomorrow's World	2
Total	9

Table 4.2

Total Number of Times 'If' is Used in Sample

	Number	Percentage
<u>Concepts in Science</u>	244	35.108
<u>Science a Modern Approach</u>	269	38.705
<u>Science for Tomorrow's World</u>	182	26.187
Total	695	100

2. on condition that:
   e.g. I shall go if you will.

3. whether:
   e.g. I wonder if he will go.

4. (informal) although; even though:
   e.g. If he is little, he is strong.

Three sentences, all of them found in the textbook Concepts in Science, contain 'as if.' The meanings and uses of 'as if' are quite different from 'if.' As a result, the three sentences with 'as if' were not used in further analysis. This left a total of 683 sentences in which 'if' is used 692 times as data for closer examination.

Table 4.3 shows the frequency and distribution of 'if' in the three science textbooks according to the meanings of 'if.' The majority of sentences, more than 75 percent, use 'if' to indicate supposition. Approximately 15 percent of the sentences use 'if' as a true conditional. The use of 'if' to mean 'whether' is used in more than 8 percent of the sentences. Less than 1 percent of the sentences use 'if' in an informal manner, confirming expectations of formal language in textbook writing.

An attempt was made to establish the reliability of determining the meanings of 'if' present in the sample sentences. To accomplish this, two independent judges, both of whom had done graduate work at university, were asked to ascribe one of the four meanings to every 'if' found in each sentence of the textbook sample.

The inter-judge reliability was calculated according to the Arrington Formula (1932, cited by Feifel and Lorge, 1950, p. 5). The

Table 4.3

Distribution and Frequency of 'If' According to Meaning

	1 Supposition		2 Condition		3 Whether		4 Informal		
	No.	%	No.	%	No.	%	No.	%	Total
Concepts in Science	182	75.519	35	14.522	22	9.129	2	0.830	241
Science a Modern Approach	219	81.413	20	7.435	29	10.781	1	0.371	269
Science for Tomorrow's World	121	66.484	51	28.022	9	4.945	1	0.549	182
Total	522	75.434	106	15.318	60	8.671	4	0.577	692

formula is

$$\frac{2 \times \text{agreements}}{2 \times \text{agreements plus disagreements}} .$$

The percentage of agreement among the three judges were as follows:

Independent Judges	Percentage of Agreement
1 + 2	94.942
1 + 3	85.260
2 + 3	87.139

Judge 1 was the investigator. Of the total incidence of 'if' analyzed, 692, there was agreement among all three judges on 577, or 83.261 percentage of agreement.

It is evident that judge 3 ascribed meanings to 'if' somewhat differently than did judges 1 and 2. The greatest disparity occurred in those sentences in which judges 1 and 2 tended to attribute the meaning of supposition to 'if,' which judge 3 perceived as a conditional. It is possible that the third judge has a more liberal view of what constitutes a condition as opposed to a supposition. Although there was some disagreement among the judges about what constitutes a supposition and what constitutes a condition, there was complete agreement among all three judges about the use of 'if' to mean 'whether,' and on the informal use of 'if.'

Syntactical and Logical Complexities in Sample

According to theories of transformational grammar, a number of grammatical transformations found in the sentences of the sample

would serve to increase the complexity of the sentences at both the surface structure level, and deep structure or meaning level. These transformations include changes in word arrangement, the question transformation, deletion of 'then' in statements of consequence, and various forms of negation.

Sentence Position of 'If' and Variations in 'If-Then' Order

Analysis of sentence data revealed that 'if' is present in a number of positions within sentences. It is used to begin sentences, it is found near the beginning of sentences following another connective, and it is found in the middle of sentences.

Sentences which begin with 'if' are written in the familiar classic conditional form in which 'if' clearly introduces the antecedent and 'then' follows to introduce the consequent.

> e.g. If heat is the energy of moving molecules, then heat energy is one kind of kinetic energy (Concepts in Science, p. 63).

Of the total number of times 'if' is used in the three textbooks, slightly more than 57 percent begin sentences to introduce the condition or conditions, after which 'then' (whether stated or implied) introduces the consequent.

Most of the sentences in which 'if' occurs in medial sentence position reverse the classical positions of antecedent and consequent. The reader must recognize the inversion of the familiar word order in these sentences. More importantly, such sentences reverse the logical form of 'if-then' statements. The reader must be cognizant of the inversion in logical form, distinguish between the antecedent

and consequent, and derive the logical form of the conditional.

> e.g. The object must move if work is done (Concepts in Science, p. 184).
> (If work is done, then the object must move.)

The sentences in which 'if' is present in medial position often contain additional discrete items of information at the beginning of the sentence which also need to be considered by the reader. This increases both the grammatical and logical complexity of the sentence and demands greater rigor in thinking to process the sentence according to the meaning intended by the author. The following sentence is an example of such complexity.

> Imagine for a moment that you believe, as Aristotle did, that an object keeps moving only if a steady force is applied (Science for Tomorrow's World, p. 70).

In some of the sample sentences information that needs to be considered prior to and in addition to the conditional statement is found in a previous sentence.

> e.g. But after a while the constant force does not make the bicycle go faster. If it did, you would ride faster than the fastest jet after a while (Science for Tomorrow's World, p. 75).

Sentences beginning with other logical connectives such as 'however' require an additional logical operation to process. Information in the 'if' sentence must be related precisely to previous information by means of 'however.'

> e.g. However, if a female enters his territory, the male may do a zigzag dance, which is his way of inviting the female stickleback to enter the nest and deposit her eggs (Science for Tomorrow's World, p. 308).

The following sentence illustrates the complexity in having to consider necessary information from a previous sentence as well

as having to derive the 'if-then' form from the reversed logical order.

> Possibly they may be used as a means for human beings to communicate with the creatures of other worlds—if they exist (Science for Tomorrow's World, p. 361).

Table 4.4 shows the distribution of 'if' according to its sentence positions in the three textbooks.

Table 4.4

Distribution of 'If' According to Sentence Position

	Initial Position		Initial Position with Previous Information to be Considered		Medial Position ('If-Then' Order Reversed)		Total
	No.	%	No.	%	No.	%	No.
Concepts in Science	133	55.187	51	21.162	57	23.651	241
Science a Modern Approach	145	53.903	27	10.037	97	36.060	269
Science for Tomorrow's World	118	64.835	26	14.285	38	20.880	182
Total	396	57.225	104	15.029	192	27.746	692

The textbook Science a Modern Approach contains the greatest number, more than half the total found in all three textbooks, of 'if' in medial sentence position resulting from reversal of the 'if-then' order. The textbook Concepts in Science contains almost twice as many 'if' sentences in which previous information must be considered

as do the other two textbooks. These may be factors in the relative difficulty which pupils may have in comprehending sentences containing 'if' in these two science textbooks.

Question Transformation in Sample

Table 4.5 shows the number of times the question transformation is used in sentences containing 'if' in the three science textbooks.

Table 4.5

Frequency and Distribution of the Question Transformation in Sentences Containing 'If'

	Number of 'If' Sentences	Number of 'If' Questions	Percentage
Concepts in Science	237	31	13.080
Science a Modern Approach	266	100	37.594
Science for Tomorrow's World	180	18	10.000
Total	683	149	21.816

The question transformation is present in 149 of the total sample of 683 sentences. Many of the sentences which pose a question involve the use of 'if' to mean supposition and reverse the 'if-then' order.

> e.g. What would happen if a red colored light shone upon a surface that absorbs red? (Science a Modern Approach, p. 328)

Of the total number of sentences which use 'if' to indicate supposition, 522 (Table 4.3), more than one quarter use the question transformation. The incidence of the question transformation in these

sentences is highest in the textbook Science a Modern Approach, twice that of the total found in the other two textbooks.

Deletion of 'Then' in Sample

Of the total 683 'if' sentences in the three textbooks, only 30 actually contain 'then' in stated form.

> e.g. If the distance is greater for the same period of time, then the speed must be greater (Science for Tomorrow's World, p. 80).

Table 4.6 shows the frequency and distribution of sentences which use 'then' explicitly.

Table 4.6

Number of 'If-Then' Sentences Stating 'Then' to Introduce Consequent

	Number of 'If-Then' Sentences	Number of Sentences Stating 'Then'	Percentage
Concepts in Science	153	12	7.843
Science a Modern Approach	140	8	5.714
Science for Tomorrow's World	134	10	7.463
Total	427	30	7.026

Some of the 683 sentences, however, would not be expected to use 'then.' The word 'then' is not implicit in the 60 sentences which use 'if' to mean 'whether' and the 4 sentences in which 'if' is used informally (Table 4.3). Of the remaining 621 sentences a total of 192 reverse the 'if-then' order (Table 4.4), in which case the first

portion of the sentence states the consequent and is not explicitly introduced by 'then.' This leaves a total of 427 sentences in which 'then' could and perhaps should be used to introduce the consequent. Only 30 of these sentences or less than 10 percent, explicitly state 'then.'

Table 4.7 shows the distribution of 397 sentences in which 'then' is deleted from 'if-then' statements.

> e.g. If a substance that remains in the same place gains weight, (then) it must have more mass (Science for Tomorrow's World, p. 21).

Table 4.7

Frequency and Distribution of 'Then' Deletion in 'If-Then' Sentences

	Number of 'If-Then' Sentences	Number of Sentences with 'Then' Deletion	Percentage
Concepts in Science	153	141	92.157
Science a Modern Approach	140	132	94.286
Science for Tomorrow's World	134	124	92.537
Total	427	397	92.974

All three science textbooks liberally use sentences in which 'then' is implied but not stated explicitly. The prevalence of sentences with 'then' deletion may have serious implications for children's reading of these textbooks, since it reduces clues to meaning and is foreign to children's language structure.

<u>Negation in Sample and Its Effects on Logical Forms</u>

The use of negation in sentences requiring the use of propositional conditional logic is of special concern to the investigator. In addition to being a grammatical transformation involving negative expansions, negation is a special form of propositional logic. The types of negation in a conditional statement can vary, and each type requires a different propositional logic.

Six different types of negation were identified in the total of 98 sentences containing both 'if' and a form of negation, either 'not, 'n't,' or 'no.' In the forms of propositions which follow, p stands for the antecedent introduced by 'if,' and q stands for the consequent introduced by 'then' in stated or implied form.

1. If <u>not</u> p, then q.

   <u>e.g.</u> If <u>no</u> outside force is exerted on an object, the object will remain at rest or will continue to move in a straight line at a constant speed (<u>Science for Tomorrow's World</u>, p. 93).

2. If p, then <u>not</u> q.

   <u>e.g.</u> If all the air is pumped out, the ringing bell will <u>not</u> be heard at all (<u>Science for Tomorrow's World</u>, p. 195).

3. If <u>not</u> p, then <u>not</u> q.

   <u>e.g.</u> If it were <u>not</u> for green plants, there would be <u>no</u> oxygen in the air (<u>Science for Tomorrow's World</u>, p. 240).

4. <u>Not</u> q if p.

   e.g. An object at rest does <u>not</u> move if forces on it are equal in size and are from opposite directions (<u>Science for Tomorrow's World</u>, p. 232).

5. q if not p.

   e.g. A steel bridge can corrode if it is not covered regularly with a protective coat of paint (Concepts in Science, p. 79).

6. Not q if not p.

   e.g. The moving objects that you see around you do not move after a while if no force acts to keep them going (Science for Tomorrow's World, p. 67).

The various types of negation listed above may each present special difficulties in reading comprehension. Table 4.8 shows the distribution of these forms of negation in sentences containing 'if' in the three science textbooks. The three textbooks contain an almost equal total number of such sentences proportionately.

Other Grammatical Processes Contributing to Syntactic and Logical Complexity of Sample

A number of sentences given as examples above also include conjoining, subordinating and embedding of ideas within sentences. According to the transformational grammar theory of linguistics, each of these factors would increase both syntactic (surface structure) and semantic (deep structure) complexity. In addition, they compound difficulties already present in logical forms of many of the sentences.

The greater the number of phrases and clauses within a sentence, the greater the number of ideas which need to be remembered and interrelated. The number and types of relational terms connecting phrases and clauses, including coordinating and subordinating conjunctions, prepositions and relative pronouns, need to be considered as potential sources of additional difficulty in the reader's

Table 4.8

Forms of Negation in Sentences Containing 'If'

	1 If not p, then q	2 If p, then not q	3 If not p, then not q	4 Not q if p	5 q, if not p	6 Not q if not p	Total	Percent.
Concepts in Science	15	8	8	1	3	0	35	35.714
Science a Modern Approach	21	14	1	1	4	0	41	41.837
Science for Tomorrow's World	10	8	1	1	1	1	22	22.449
Total	46	30	10	3	8	1	98	100

comprehension of conditional statements and the complete sentences which incorporate them. A sentence such as the following one may be incomprehensible even to the most gifted grade six pupil.

> This is the motion you expect according to Newton's First Law of Motion, which says that if no new force is exerted on an object, the object will remain at rest or will continue to move in a straight line at constant speed (Science for Tomorrow's World, p. 77).

Although the conjoining, subordinating and embedding of ideas within sentences need to be considered as possible hindrances to reading comprehension, they are not within the scope of the present study. Thus, there was no attempt to analyze the sample for these grammatical processes.

Summary of Textbook Findings

This chapter presented and analyzed some factors of grammar, syntax and logic present in sentences containing 'if' used in science textbooks for grade six children which may compound difficulties in reading comprehension of the material.

Differential uses of 'if' according to meanings of 'if' given in The Intermediate Dictionary were examined. It was found that all three textbooks use 'if' to indicate supposition in a great majority of the sentences. The conditional use of 'if' and 'if' to mean 'whether' are also used in large numbers. Inter-judge reliability calculations indicate that the differential uses of 'if' as supposition and condition are not always clear and may be a source of confusion even to adults.

The sentences were examined for a variety of grammatical

transformations which linguists have identified as increasing the syntactical complexity of sentences. A number of the transformations directly affect the logical form and thereby add to the logical complexity of the sentences in which they are present. Factors analyzed as contributing to syntactical and logical complexities of sentences include changes in word arrangement (specifically, sentence positions of 'if' and 'if-then' inversion), the question transformation, deletion of 'then' in statements of consequence, and various forms of negation.

The majority of sentences in the three textbooks use 'if' in initial sentence position. A large number of sentences, however, require that the reader consider information contained in a previous sentence. More than one third of all sample sentences reverse the logical 'if-then' form.

The question transformation is present in more than two-fifths of the sentences, many of them involving 'if-then' order inversion.

Deletion of 'then' to introduce the consequent is widespread in sentences in all three textbooks. Less than 10 percent of the sentences which have a structure in which 'then' could be stated actually use 'then' explicitly.

The 98 sentences which include negative expansions constitute nearly 15 percent of the total sample. Six different types of negation were identified, each requiring a different form of propositional logic.

Many of the sentences in the sample have complex syntactical

structures which result from conjoining, subordinating and embedding of ideas. These factors, however, were not isolated for analysis.

This chapter analyzed some elements of grammar, syntax and logic present in sentences containing 'if' used in three science textbooks which may be critical in the reading comprehension of grade six children. All these factors are quite apart from vocabulary, concept load and sentence length which are often the only variables considered in determining suitability of textbooks for a particular group of children.

Chapter 5

SUMMARY, CONCLUSIONS AND IMPLICATIONS

Although 'if' is usually considered to be a word that is easy to read and to understand, it may pose problems in reading comprehension. Its abstract nature, multiple meanings and differential uses as a grammatical construct make precise understanding difficult for children. But 'if' is also a logical construct basic to most deductive reasoning, and to conditional logic in particular. Understanding both the grammar and logic of 'if' is a prerequisite to reasoning which includes concepts of conditionality.

Research has shown that conditional reasoning ability begins in adolescence, but it is slow to develop and presents many difficulties even in late adolescence. Nevertheless, textbooks in science used by children in the upper elementary grades freely and frequently use 'if' in a logical as well as grammatical role.

The present study was designed to examine the uses of 'if' in science textbooks used by sixth grade children.

Summary of the Study

The study involved analysis of three science textbooks used by children in grade six for sentences containing 'if.' A total of 686 'if' sentences were found in the three textbooks, and were recorded for further analysis.

Differential uses of 'if' according to various meanings were

examined. Sentences were analyzed for certain specific grammatical transformations which add to syntactic and logical complexity. These processes include changes in word arrangement, specifically sentence positions of 'if' and 'if-then' inversions; the question transformation; deletion of 'then'; and forms of negation.

Findings and Conclusions

The following questions were formulated at the outset of this study. Findings and conclusions pertinent to each question are reported and discussed.

Question #1

> What is the frequency and distribution of sentences containing 'if' in the three science textbooks recommended by the Department of Education to be used by grade six pupils in Alberta?

A total of 686 sentences containing 'if' were found in the three textbooks (Table 3.1). The textbook Science a Modern Approach has the greatest number of these sentences, 266, followed by Concepts in Science with 240. Science for Tomorrow's World with 180 has the fewest 'if' sentences.

Research has shown that children in grade six have considerable difficulty with conditional logic which makes use of 'if-then' propositions. The differences in the number of sentences containing 'if' and conditional statements may be one indication of the relative difficulty of individual textbooks.

Question #2

> What is the total number of times the word 'if' is used in sentences in the textbooks?

Nine of the sentences in the total sample use 'if' twice (Table 4.1), yielding a total of 695 times the word 'if' is actually present in sentences in the three textbooks (Table 4.2).

The presence of a double conditional will undoubtedly greatly complicate the logic of the sentence. The logical complexity results from the necessity of precisely interrelating two conditional statements. Moreover, constraints on logical reasoning are likely to be increased further by the greater syntactic complexity of the sentence.

Question #3

> What are the differential uses of 'if' according to differences in meaning of the word 'if' in the sentences?

The Intermediate Dictionary (Gage, 1963, p. 441) gives four meanings of the conjunction 'if':

1. supposing that or in case that
2. on condition that
3. whether
4. although or even though (informal).

Table 4.3 shows that more than 75 percent of the sentences use 'if' to indicate supposition, which requires pupils to consider hypothetical and often abstract relationships. Approximately 15 percent of the sentences use 'if' as a true conditional requiring the rigor of conditional logical reasoning. The use of 'if' to mean 'whether' is used in more than 8 percent of the sentences. As expected, 'if' is rarely used in an informal manner in sentences in the textbooks.

The language of textbooks is formal, and informality is rare in scientific writing in particular.

These findings clearly indicate that function words do not have a single meaning, and that they have differential uses even within one area of study. The conditional 'if-then' statement is an integral part of scientific language. Most people recognize the rigor that characterizes scientific language, and perhaps assume that uniformity of expression implies uniformity of meaning. The presence of 'if' in sentences of similar structure to indicate supposition and condition may be surprising to those who assume that 'if' has a single meaning and a single use in scientific writing.

At present, it is not known whether sentences containing differential uses of 'if' pose different problems in comprehension of the word 'if' and of the sentence as a whole. It is possible that 'if' used as a supposition may require a thinking process different from that of 'if' used as a conditional. Pupils do need to be able to distinguish the two forms and what they imply. The use of 'if' to mean 'whether' clearly demands the identification of this meaning in order that the sentence be understood.

The decision making process that must take place to determine the correct meaning of 'if' in a particular context may be very difficult for grade six pupils. The independent judges who participated in the reliability study of the meanings of 'if' in the present investigation appeared to have some difficulty in ascribing meanings of condition and supposition.

Studies by Robertson (1966) and Rawson (1969) show that the word 'if' creates problems in reading comprehension for elementary

school children. As a result of his research, Ennis (1965) postulated that adolescents had difficulty learning conditional logic because they did not understand the meaning of the conditional 'if.'

Question #4

What are the sentence positions in which 'if' is located?

It was found that 'if' is present in a number of positions within sentences:

1. initial sentence position
2. initial sentence position with previous information to be considered
3. medial sentence position (resulting from 'if-then' inversion).

Table 4.4 gives the frequency and distribution of 'if' according to sentence position in the three textbooks.

The classical form of the conditional sentence is the 'if-then' form. The 'if' introduces the antecedent which states the condition or conditions, and is followed by 'then' introducing the consequent of the condition. This is the expected logical and grammatical order of conditional statements. Its familiarity may make it the most easily understood form of 'if-then' sentences. Of the total number of times 'if' is used in the three textbooks, slightly more than 57 percent begin sentences.

In approximately 15 percent of the cases in which 'if' occurs at or near the beginning of a sentence in the classical 'if-then' form, there is previous information that must be considered in the comprehension of the sentence as a whole. The extra information may

be in a previous sentence, or it may begin the 'if' sentence. The additional discrete items of information increase both the grammatical and logical complexity of the sentence. There is need for greater rigor in thinking to process the sentence in order to derive the intended meaning. The meaning of the message must be relevant to the writer's thought, not to idiosyncratic thinking of each reader.

Research by Piaget and his associates indicates that before the age of ten or eleven the child is not capable of purely hypothetico-deductive reasoning. Before the formal reasoning stage is attained the child is bound by idiosyncratic thought particularly in the area of relational logic. Most sixth grade children would be trapped by idiosyncratic reasoning if they do not receive specific instruction.

The need to consider previous information increases the demands on a reader in a number of ways. It places a strain on short-term memory, it necessitates correctly relating a number of discrete items of information, and in the case of sentences beginning with other logical connectives (for example, however), it requires an additional logical operation.

More than 27 percent of the times that 'if' is used in the sample, it is found in medial sentence position, the result of 'if-then' inversion.

Reversal of the 'if-then' order is both a logical and a grammatical rearrangement. Such an inversion reverses the logical form of the conditional. The reader must recognize the inversion in logical form, distinguish between the antecedent and consequent, and derive the logical form of the conditional.

The grammatical rearrangement of the 'if-then' order increases syntactic complexity. The change in the expected word order violates the reader's expectations and predictions which may interfere with the processing of the sentence. 'If-then' inversions are infrequent in oral language, not highly predictable in reading, and require a refocusing which may well be difficult for the young reader to process.

Since more than one quarter of all sentences in the sample reverse the 'if-then' order, the prevalence of this logical and grammatical form may be a factor in the comprehensibility of the science textbooks.

Question #5

> To what extent is the question transformation used in sentences containing 'if' in the three textbooks?

Table 4.5 shows the number of times 'if' sentences are written in question form. More than one fifth of the total sample was found to use the question transformation. Of the total 'if' questions, fully half are found in the textbook Science a Modern Approach. This textbook makes extensive use of questions. Of all its sentences containing 'if,' more than one third are in question form.

It was found that most sentences which pose a question involve the use of 'if' to mean supposition and 'if-then' inversion. The use of this specific meaning of 'if' and the syntactic style of the question containing 'if' must be recognized. The question refers to information in a specific linguistic form. The analysis and processing required to answer a question may add an extra measure of difficulty.

Question #6

> How often is 'then' stated in 'if-then' sentences, and to what extent is it deleted but implied?

One of the most unexpected findings which may relate to comprehensibility of science textbooks is the great prevalence of 'then' deletion in 'if-then' statements. Only 30 sentences in the total sample state 'then' to introduce the consequent. This is approximately 7 percent of all sentences written in the classic 'if-then' form in which 'then' is used explicitly to introduce the consequent. In 93 percent of such sentences, however, 'then' is merely implied.

Research has shown that children do not omit 'then' from their speech or writing. As a result, the grammar of deletion produced structures is negatively related to reading comprehension (Fagan, 1969; Cosens, 1974).

The reader must also supply the missing 'then' in order to derive the logic of the 'if-then' form before he can process the logic of an 'if-then' statement. This adds an extra measure of difficulty to children's already weak understanding of the logic of conditionals.

Many of the prevalent readability formulas use sentence length as a variable. The assumption is that the shorter the sentence, the less difficult it will be to read. Creators of readability formulas and textbook writers cannot assume that a sentence made more compact by means of deletion will be easier to understand simply due to its shorter length. Deletion reduces clues to meaning, thereby adding to sentence difficulty.

Question #7

> What use is made of negative expansions and what are the effects of negation on the logical forms of sentences containing 'if'?

A total of 98 sentences were found to use the negative 'not,' 'n't,' or 'no.' In addition to being a grammatical transformation, negation is a special form of propositional logic. There can be various types of negation in conditional sentences, each requiring a different propositional logic.

Six different types of negation were identified. They can be stated as different forms of propositions in which p = condition or antecedent, and q = consequent.

1. If not p, then q.
2. If p, then not q.
3. If not p, then not q.
4. Not q if p.
5. q, if not p.
6. Not q if not p.

These forms of propositions are not among the chief forms of conditional reasoning (modus ponens and modus tollens) formulated by logicians. They may be used infrequently and be less familiar to anyone applying principles of logic.

Table 4.8 shows the frequency and distribution of the six forms of negation in the three science textbooks. Some forms are used more frequently than others. Form (1) If not p, then q, is used most frequently in all textbooks, followed by form (2) If p, then not q. The textbook Science a Modern Approach makes the greatest

use of these two forms of propositions, and contains the greatest percentage of all sentences with negative expansions.

Ennis's (1965) research on adolescents' conditional reasoning ability used 12 principles of conditional logic (see Appendix), some of which are arguments involving negation. He found children aged eleven to twelve unable to reason according to most of the principles. The results of research by Piaget and Ennis suggest that sixth grade pupils will have difficulty dealing with the most basic forms of conditional logic. More complex forms such as those resulting from one or two negative expansions may present excessive difficulty. This difficulty may be compounded by additional complexity of the context of the logical form which is the sentence containing the 'if-then' proposition.

Writers of children's textbooks need to be aware of the logical as well as the grammatical changes in sentences created by negative expansions. Where use of negation affects logical form, as it does in 'if-then' sentences, negatives must be used very cautiously.

Implications of the Study

A number of implications for textbooks and for those who write them and evaluate them, as well as for classroom teachers of all subject areas arise from the results of this study.

Implications for Textbooks

Writers of science textbooks must recognize that 'if' has multiple meanings and can assume several functions in sentences even in scientific writing. The difficulties with 'if' may be compounded

by the child's lack of awareness of the subtleties in multiple meanings of words and ignorance of the fact that he may not understand the words precisely in various contexts.

Textbook writers, editors and those charged with evaluating the difficulty of textbooks used by children in the elementary grades need better tools for assessing factual, informational written material than is available by means of traditional readability formulas. Not only do readability formulas fail to accurately measure readability of non-narrative writing, they make no attempt to evaluate its comprehensibility to children whose cognitive development is immature.

All those who are concerned with preparation and evaluation of scientific materials written for children can obtain insightful knowledge from the study and research in syntactic complexity and logical reasoning. Writers of textbooks to be used by children must be aware of language processes which contribute to its grammatical and logical complexity, and control those which may cause undue difficulties in reading. More extensive use should be made of the cloze procedure and logical reasoning testing based on the grammar and logic used in the textbooks. This would yield indices of children's comprehensibility of grammatical and logical textbook content. The result will be textbooks children are able to read and derive information from both independently and with appropriate instruction.

Implications for Teachers

Teachers need to be aware of multiple meanings and differential uses of grammatical words in written material. Science teachers must recognize the differential uses of 'if' found in science textbooks. In the light of the analysis and research, multiple meanings and uses should be discussed and illustrated within their respective contexts. Children also need to be made aware of the various possibilities regarding placement in sentences the word 'if' is able to assume.

Teachers need to teach the logic as well as the grammar of the word 'if.' When teaching the logic of the conditional 'if' they should use the simplest logical forms and sentence forms possible.

Beginning in the elementary grades, children need to be offered systematic instruction in logical reasoning, including conditional reasoning. If children are taught forms of logical argument they may learn to recognize valid and invalid forms of reasoning in their reading material. More importantly, because scientific thinking involves the use of hypothetico-deductive reasoning, children need to be led, step by step, into making valid inferences and reaching valid conclusions, as well as evaluating those in their science textbooks. Logical standards can also be applied to inferences made by children in order to subject them to critical analysis. In order to evaluate an inference it is necessary to consider the relation between a conclusion and the evidence from which the conclusion is drawn. In this way children can be taught to avoid the traps which lead to fallacious reasoning.

Teachers need to keep in mind the stages of logical development

as they plan experiences and dialogue activities for their pupils, recognizing the limitations and exploiting the possibilities of each stage. They need to stretch children's thinking as much as possible in the stage they are in, as well as lead them toward a higher stage. They should remember that because of individual differences a child may be at different stages in different areas of cognitive ability, and that children in the same age group may be generally at different stages.

To allow pupils to obtain an experiential framework for scientific concepts, teachers can provide a hierarchy of pupil involvement. Providing pupils with concrete experiences in an area before they are asked to read about it might facilitate acquisition of the particular concept.

Science textbooks may be too difficult for independent reading by the majority of the children for whom they are intended. Without deliberate and specific reading instruction children will fail to achieve full comprehension of the author's thoughts. Teachers can also help children cope with science information by having a variety of supplemental reading material available to accommodate different reading levels.

Skillful use of questions and on-the-spot discussion of meanings in textbook writing is probably one of the best means of enhancing reading comprehension and of clearing up misunderstandings and erroneous reasoning. The teacher must become skilled in the art of diagnostic questioning techniques.

Teachers of content subjects such as mathematics, science and

social studies need to know the types of language structures used in their content area textbooks, and teach children to analyze them. In as much as teachers of content subjects must teach their pupils to read textbooks, they are also teachers of reading.

Suggestions for Further Research

A number of related studies could be designed to investigate various aspects of the present study.

Now that it is known what grammatical and logical structures containing 'if' are present in three grade six science textbooks, it would be desirable to test children's reading comprehension of the grammar and logic of 'if' in the variety of contexts used in the textbooks.

The sample of sentences in these textbooks can be analyzed further for additional processes of syntactic complexity, including conjoining, subordinating and embedding of ideas by means of other relational words used in the textbooks. Children's reading comprehension of these structures could then be investigated.

A study which analyzed the same type of sentences and structures found in the same textbook series used in other elementary grades would provide some basis for comparison of relative complexity across grades. Investigation of children's comprehension of these structures in various grades may determine the nature of the developmental trend in the understanding of the grammar and logic of 'if.'

A study which explored other textbooks used in elementary and junior high school grades, particularly mathematics which makes

special use of 'if-then' propositions in formulation of mathematical problems, would provide more complete information about the grammar and logic of 'if' in sentences children are expected to read.

Children appear to have difficulty understanding and solving problems in mathematics which are expressed in language structures although they may have the necessary computation skills. It would be desirable to find the extent to which difficulties in reading comprehension hinder problem solving.

The present study analyzed only the written aspect of the word 'if.' Studies could be designed to explore children's exposure to, use and understanding of 'if' in the other communication processes: speaking, writing and listening.

Concluding Statement

This study shows the extent to which children in grade six are exposed to the word 'if' in sentences found in their science textbooks. The grammar and logic of 'if' as it is used in the sentences were examined, as were selected grammatical processes which may increase syntactical and logical complexity. This exploratory study may provide some insight into possible reasons for reading difficulty of science textbooks. It may also indicate some grammatical and logical factors in textbook comprehensibility.

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APPENDIX

Illustrated Basic Principles of Conditional Logic

(Ennis, 1967, pp. II-10 and 11)

Principle	Symbolized Argument	Concrete Argument
1. Given an if-then sentence, the affirmation of the if-part implies the affirmation of the then-part.	If p, then q. p. Therefore q. Valid.	If the hat on the table is blue, then it belongs to Joan. The hat on the table is blue. Therefore the hat on the table belongs to Joan.
2. Given an if-then sentence, the denial of the if-part does not by itself (as a result of its being an if-part) imply the denial of the then-part.	If p, then q. Not p. Therefore not q. Invalid.	If Tom lives in the white house, then his last name is Smith. Tom does not live in the white house. Therefore Tom's last name is not Smith.
3. Given an if-then sentence, the affirmation of the then-part does not by itself (as a result of its being a then-part) imply the affirmation of the if-part.	If p, then q. q. Therefore p. Invalid.	If Mary lives in the white house, then her last name is Brown. Mary's last name is Brown. Therefore Mary lives in the white house.
4. Given an if-then sentence, the denial of the then-part implies the denial of the if-part.	If p, then q. Not q. Therefore not p. Valid.	If the car in the parking lot is Mr. Smith's, then it is blue. The car in the parking lot is not blue. Therefore the car in the parking lot is not Mr. Smith's.
5. The if-then relationship is transitive.	If p, then q. If q, then r. Therefore, if p, then r. Valid.	If Sam misses the bus, he will walk to school. If Sam walks to school he will cross the bridge. Therefore, if Sam misses the bus, he will cross the bridge.

Principle	Symbolized Argument	Concrete Argument
6. An if-then sentence implies its contrapositive.	If p, then q. Therefore, if not q, then not p. Valid.	If Mrs. Smith entered the flower show, then she entered her roses. Therefore, if Mrs. Smith didn't enter her roses, then she didn't enter the flower show.
7. The if-then relation is non-symmetric.	If p, then q. Therefore, if q, then p. Invalid.	If the chair is green, then the table is black. Therefore, if the table is black, then the chair is green.
8. Given an only-if sentence, the denial of the only-if part implies the denial of the major part.	p only if q. Not q. Therefore not p. Valid.	John is in the kitchen only if there is food in the kitchen. There is no food in the kitchen. Therefore John is not in the kitchen.
9. Given an only-if sentence, the affirmation of the major part implies the affirmation of the only-if part.	p only if q. p. Therefore q. Valid.	Harry is on the football team only if he has his mother's permission. Harry is on the football team. Therefore Harry has his mother's permission.
10. The denial or affirmation of one part of an if-and-only-if statement implies respectively the denial or affirmation of the other part.	p, if, and only if, q. Not p. Therefore not q. Valid.	Bill will see Audrey this year, if, and only if, he goes to Montreal this year. Bill will not see Audrey this year. Therefore, Bill is not going to Montreal this year.
11. Given an only-if sentence, the affirmation of the only-if part does not by itself (as a result of its being an only-if part) imply the affirmation of the major part.	p only if q. q. Therefore p. Invalid.	Dick is using the classroom dictionary only if the library is closed. The library is closed. Therefore Dick is using the classroom dictionary.

Principle	Symbolized Argument	Concrete Argument
12. Given an only-if sentence, the denial of the major part does not by itself (as a result of its being the major part) imply the denial of the only-if part.	p only if q. Not p. Therefore not q. Invalid.	Jane went to the park yesterday only if she saw her friend Pat yesterday. Jane did not go to the park yesterday. Therefore Jane did not see her friend Pat yesterday.